An Engineering Laboratory Experience for a Freshman Engineering Class

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Introduction

Engineering laboratory experiences are different from science laboratory experiences in that they are more focused on problem solving rather than discovery. Hence, it would seem important to introduce freshmen engineering majors to this difference by giving them an exposure to an engineering laboratory. The mechanical engineering section of the Residential Option for Engineering and Science Students (ROSES) at Michigan State University was given such an opportunity. The ROSES program at MSU is intended as an enrichment program for the best and brightest of the pre-engineering majors. To achieve this, ROSES students are clustered in the dormitories as well as their pre-engineering classes (such as calculus, physics, and engineering graphics). They also attend a weekly, one and a half hour seminar class during the first semester of their freshman year, which is intended to provide an introduction to engineering and assist in the transition from high school. Enrichment is provided during this seminar through several activities including talks from practicing engineers, personality testing, impromptu design projects, and dissection projects. Hence, providing an engineering laboratory experience within this seminar is very consistent with the goals of the ROSES program.

As an assignment for the seminar class, the students were organized into groups of three and given an exercise to be conducted in the department's Heat Transfer Teaching Laboratory. In the assignment students were asked to predict quantitatively several behaviors associated with convective heat transfer. To provide data, a simple experiment dealing with the convective heat transfer from a cylinder was conducted. This provided the students with exposure to several engineering laboratory issues including:

- simple laboratory modeling of a complex physical process
- use of dimensionless parameters
- development and use of a predictive model to solve a problem

Additionally, students were allowed to practice their teaming skills through the planning and implementation aspects of the assignment and their communication skills through the reporting phase. This paper continues by providing the details on the assignment, student feedback on the experience, and the lessons learned by the authors.

The Assignment

The students were provided with a handout that explained the assignment. The assignment began with a lecture in the seminar class that introduced the students to heat transfer. This included the basic definition of heat transfer as an energy transport mechanism that occurs when energy moves from a body of high temperature to a body of low temperature. Several examples of the three different modes of heat transfer (conduction, convection, and radiation) were provided. In particular, the two convective heat transfer problems shown in Figure 1 were presented. At this point, Newton's law of cooling was introduced as the predictive model for convective heat transfer. This was done with both the verbal equation shown below,

[heat transfer rate] = [convective heat transfer coefficient] x [surface area]
x [(surface temperature) – (fluid temperature)]

and symbolically

$$\dot{Q} = hA_{surface}\left(T_{surface} - T_{fluid}\right)$$

The nature of the convective heat transfer coefficient, h, was then discussed, extensively using the example of the wind chill factor (a concept with which all students in Michigan are familiar).

The idea of using an experiment to determine the convective heat transfer coefficient from experimental measurements was then introduced. The experimental apparatus that was used is shown in Fig. 2. It is a set-up that should be available in many mechanical or chemical engineering teaching labs. The students were provided with the experimental procedure shown in Fig. 3. Basic lab protocol and safety were reviewed with the students.

Figure 1 Two Convective Heat Transfer Problems

<u>Airplane-Wing Anti-icing</u>

For light aircraft it is very important for the wings not to ice up when it is traveling at a very high and cold altitude. We would like to know how much heating must be provided to keep the wings from icing up. Some pertinent information:

Temperature of air at plane altitude: -40°C
Wing surface area: 14 m^2
Plane speed: 100 m/s
Effective wing diameter: 0.75 m

<u>The Polar Bear Run</u>

We wish to know the skin temperature we would achieve during a polar-bear run. Some pertinent information:

Temperature of air: -10°C
Body surface area: 2 m^2
Person speed: 0.2 m/s
Effective body diameter: 0.3 m
Body metabolic rate: 150 W

Figure 2 Layout of Experiment

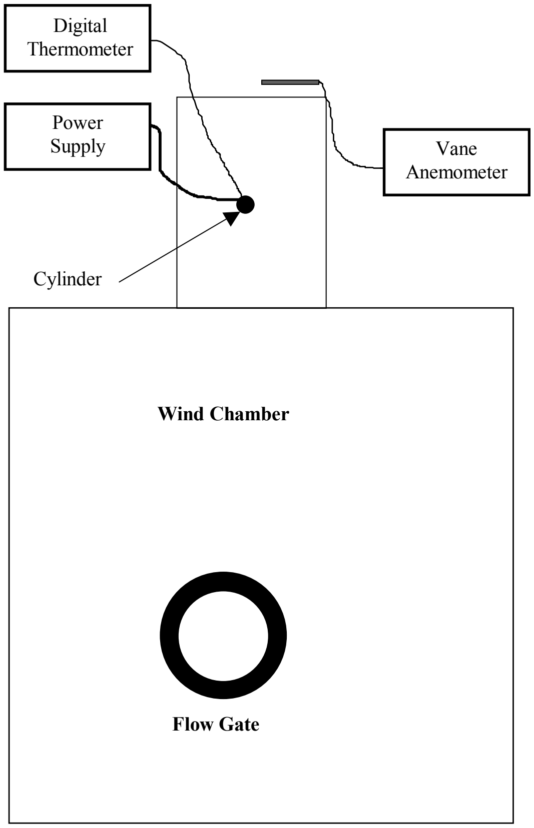


Figure 3 Experimental Procedure

1. Check that the power supply is unplugged from the wall.
2. Turn on the wind chamber and set the gate to position eight.
3. Plug in the power supply and set the current to 15 amps.
4. Allow the system to stabilize and record the power supply current and voltage and the digital thermometer temperature.
5. Move the vane of the vane anemometer to the top of the wind chamber and record the air velocity and temperature.
6. Set the gate on the next position, allow the system to stabilize, and record the measurements. Repeat this step down to gate position four.
7. Set the power supply current to zero and unplug the power supply.
8. Turn off the wind chamber ONLY after the cylinder temperature has returned to room temperature.
9. Turn off all of the meters.

Record the data in the Excel spreadsheet provided. This spreadsheet will perform all of the calculations required.

The lecture concluded with a review of scaling. The students were reminded of a pre-college experience of determining the height of a tree by scaling its height with the length of its shadow and equating this to the ratio of the height of a person to the length of the person's shadow. With the measurements of the two shadow lengths and the height of the person, the height of the tree can then be calculated. This concept was shown to be applicable to the two convective heat transfer problems introduced by using the following scaling laws for convective heat transfer with the experimental measurements made. For convective heat transfer in air, we have two scaling issues: one for the velocity and one for the convective heat transfer coefficient, h. In other words, we might say that for equal velocity times length, we have equal convective heat transfer coefficient times length. Mathematically, we might write

$$\text{For } \vec{u}_1 L_1 = \vec{u}_2 L_2$$

$$\text{then } h_1 L_1 = h_2 L_2$$

To conduct the experiment an evening session was scheduled in the laboratory facility. This was a volunteer activity, yet a large fraction of the students (15 of 18) chose to participate. To develop an even more conducive learning environment, pizza and soda were provided. Students signed up for a 20-minute time slot and were told to plan to spend an hour in the lab for data collection and processing. When the students associated with the group arrived for their scheduled time, they were first given a walk though of the experiment. They were also introduced to an Excel spreadsheet template provided for recording and processing the data collected. They were encouraged to assign tasks and rotate tasks in conducting the experiment but were pretty much left alone to run the experiment once the walk through was completed. This was possible due to the simplicity, robustness, and inherent safety of the experiment and associated equipment. Following completion of data collection the group was moved to another computer in the lab facility for the processing of the data. This allowed the next group to conduct the experiment. Figure 4 shows the requested data analysis. All of the students were familiar with Excel; but most groups needed significant help in the data processing, including performing the basic calculations and the graphing of the results. They also needed significant guidance in the scaling aspects required for the heat transfer predictions requested in the

Figure 4 Required Data Analysis

1. Plot the convective heat transfer coefficient versus the velocity. Is this graph consistent with your physical understanding of convective heat transfer? (Think about the wind chill factor.)
2. Using the results of this experiment, determine the power required to maintain the cylinder at 100°C for an air velocity of 21 m/s.
3. Using the results of this experiment, determine the skin temperature of the person in the polar bear run.
4. What air velocity is needed in the laboratory in order to solve the airplane wing icing problem?

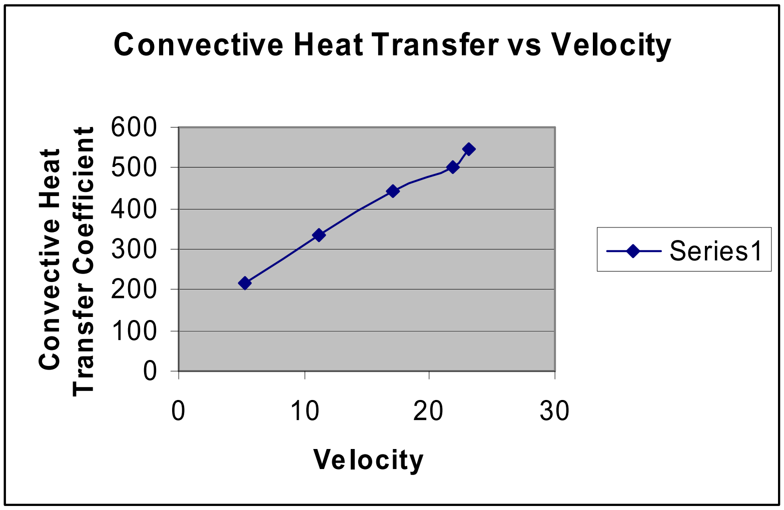
write-up. Upon completion of this aspect of the assignment, the students submitted the spreadsheet file and then completed the post lab survey. For most groups the experience lasted somewhat less than the hour scheduled. At the next seminar meeting of the ROSES class, paper copies of the students' Excel worksheet were passed out, along with the results sheet shown in Fig. 5.

Figure 5 Results Handout

ROSES - Laboratory Experience
"Convective Heat Transfer"

Results

1. Plot the convective heat transfer coefficient versus the velocity. Is this graph consistent with your physical understanding of convective heat transfer? (Think about the wind chill factor.)



2. Using the results of this experiment, determine the power required to maintain the cylinder at 100°C for an air velocity of 21 m/s.

45-60 W depending on the estimation of h

3. Using the results of this experiment, determine the skin temperature of the person in the polar bear run.

About 3°C

4. What air velocity is needed in the laboratory in order to solve the airplane wing-icing problem?

15,244 m/s

Student Feedback and Lessons Learned

Student feedback for this experience was collected using a pre-lab and a post-lab survey. The post-lab survey is shown in Fig. 6. The pre-lab survey had only the first three questions of the post-lab survey. The responses from question 3 indicate that about half the students was currently having a college level lab experience (most probably freshman chemistry lab). A comparison of questions 1-2 for the two surveys is shown in Fig. 7. From these results, it would appear that this experience improved the students' attitude towards laboratory work and convinced them that lab work can be used to solve problems as well as observe nature. The students' anecdotal comments indicated a very positive experience. They enjoyed the hands-on nature of the experience and the opportunity to spend some time in an engineering lab facility. Some selected responses for questions 4 and 5 are provided below.

4. What were the good things about the ROSES lab experience?

"Showed me how to use the lab to solve real life problems"
"In the lab, it is absolutely vital to follow the procedure word for word and follow all directions. Lab work is a hands on method for learning new material."
"I become more familiar with the engineering building. Gave us a chance to have a lab without worrying about results, or a strict procedure."
"Good hands on learning about a lab experience."
"I learned a lot about what I will be seeing in the future."
"Showed you what kind of lab work engineers will do. Showed you all the cool equipment available at MSU for engineers."

5. What were the bad things about the ROSES lab experience?

"The lab could have been done easily by 2 people, not a lot of things to be done by 3 people."
"I found the math work/solving equations to be a little confusing at times with all of the variables – that I was not familiar with."
"Nothing.
"It was short and seemed rushed."
"It took a very long time."
"I didn't know the room number."

During this experience the authors identified several opportunities for improvement and these are shared below:

- The survey results indicate that this experience improved the students' attitude towards lab work. They also become more cognizant that lab work can be used for problem solving.
- It was clear that the students' understanding and ability to use scaling was somewhat limited, contrary to the reaction received during the lecture. Some simple scaling examples need to be incorporated in the lecture portion of the assignment.
- The wide range of Excel abilities among the students might indicate a need for an Excel tutorial prior to the lab experience.

Figure 6 Post-Lab Survey

EGR 291 ROSES Seminar – Mechanical Engineering

Engineering Lab Experience Survey
Post-Lab

1. What is your general sentiment about lab work?

Love it		Neutral		Hate It
5	4	3	2	1

2. What is lab work good for?

Observing nature				Solving Problems
5	4	3	2	1

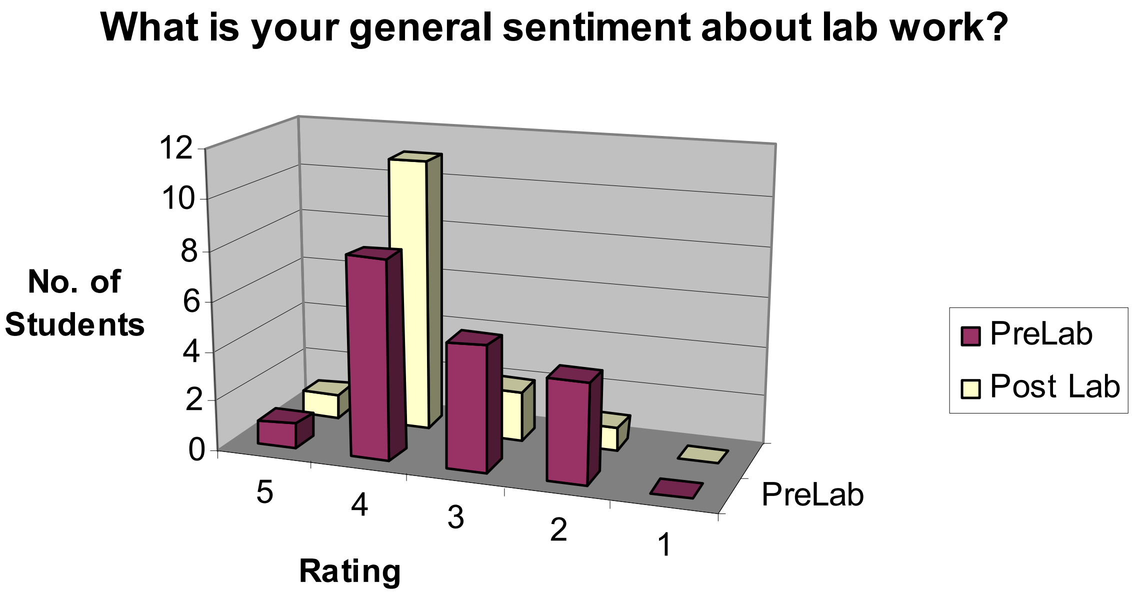
3. Have you done a college lab course?

Yes No

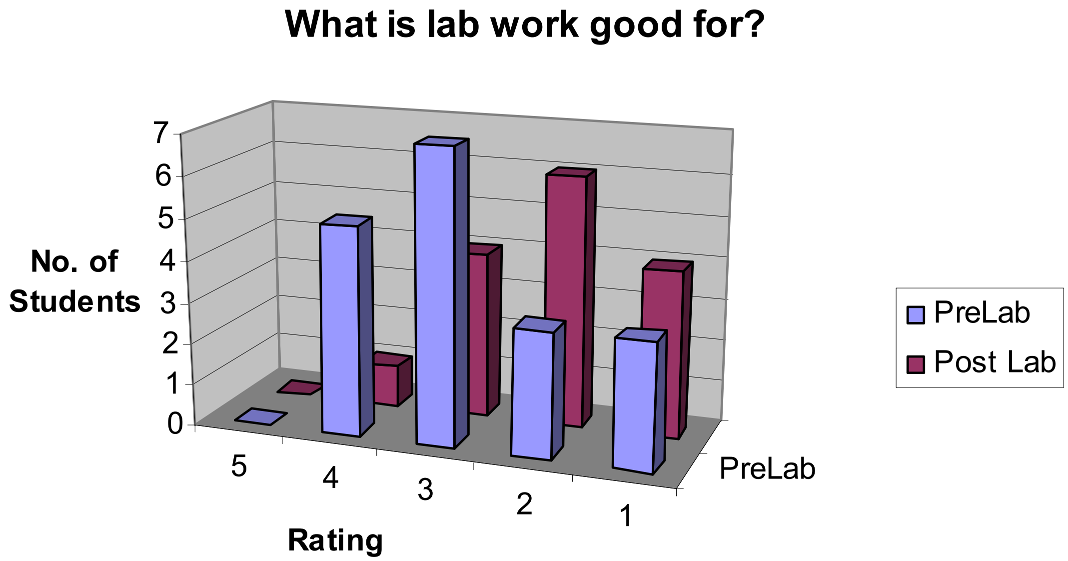
4. What were the good things about the ROSES lab experience?

5. What were the bad things about the ROSES lab experience?

Figure 7 Survey Results



What is your general sentiment about lab work?



What is lab work good for?

- Many of the students indicated a curiosity about the other equipment and experiments in the lab. This was handled via impromptu tours but might be more effectively addressed by having a tour of the department's teaching laboratories.

- By happenstance, two mechanical engineering seniors were in the lab facility during the evening session. There was outstanding interaction between them and the freshman and this experience could be strengthened considerably by recruiting seniors to assist during the lab session.

Author Biographies

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Craig W. Somerton is Associate Professor and Associate Chair of Mechanical Engineering at Michigan State University. He teaches in the area of thermal engineering including thermodynamics, heat transfer, and thermal design. Dr. Somerton has research interests in computer design of thermal systems, transport phenomena in porous media, and application of continuous quality improvement principles to engineering education. He received his B.S. in 1976, his M.S. in 1979, and his Ph.D. in 1982, all in engineering from UCLA.

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Craig J. Gunn is Director of the Communication Program in the Department of Mechanical Engineering at Michigan State University. In this role he directs the integrated communication program in mechanical engineering while providing help to the cooperative engineering education division of the College of Engineering. He has spent thirteen years of teaching in the public school system and fifteen years at Michigan State University. He serves as editor for the *CED Newsbriefs* and *MCCE Co-op Courier*.